EA466 Spacecraft Thermal Control
Homework

1. An isotropic point source radiator has a total emissive power (see page 47 of Karam) q^e. (*a*) Calculate the total directional emissive power q^e_θ (W/sr). (*b*) Calculate the power density delivered at a distance of r meters.

2. The isotropic point source radiator of the previous problem is replaced by a disc of diameter d radiating the same hemispherical total emissive power as before. The disc obeys Lambert's Law. (*a*) Calculate the total emissive power per unit normal surface area (see page 46 of Karam). (*b*) Calculate the total directional emissive power q^e_θ (W/sr). (*c*) Calculate the power density delivered at a distance of r meters.

3. A plane perfect black surface is radiating at a temperature of 833 K. What is the spectral directional emission at an angle of 60° from the normal and at a wavelength of 6 μm?

4. Rewrite the blackbody spectral directional emission

$$I^e_{\lambda,\theta}\, d\lambda = \frac{2hc^2\, d\lambda}{\lambda^5[e^{hc/\lambda kT} - 1]}$$

   in terms of the frequency ν.

5. For a blackbody to radiate its maximum spectral directional emission at the center of the visible band, what would its temperature have to be?

6. The thermal radiation emitted normal to a blackbody surface is found to have a total radiation per unit solid angle and per unit area of 3544 W/m^2-sr. What is its surface temperature? At what wavelength is its maximum spectral emission?

7. Use the Stefan-Boltzmann Law to calculate the total emission intensity of the sun (assumed to be a blackbody) at the surface of the sun. Convert this to directional emission (pay careful attention to nomenclature here). Use this to calculate the solar constant (power density at one astronomical unit).

8. Model a spacecraft as a solid aluminum sphere 1 m in diameter. Assume that all of the sunlight falling on it in low earth orbit is absorbed with none reflected and none re-radiated. Find an analytical expression for the temperature as a function of time and calculate the time required for the satellite to reach 100° C starting from an initial temperature of 0° C. Compare this time to the orbital period of a satellite in low earth orbit.

9. Quiz III re-do.

10. Beginning with Fourier's Law of Conduction (page 21 in Karam),

$$q_k = -k\frac{\partial T}{\partial n}$$

   derive the expression for the thermal conductance of a hollow sphere (page 22 of Karam)

$$K_{sphere} = \frac{4\pi k r_1 r_2}{r_2 - r_1}.$$

11. Calculate the Reynolds number, Prandtl number and Nusselt number for air moved by a typical table fan.

12. Evaluate the effectiveness of the following forced convection cooling system for high thermal capacity components (such as momentum wheels). The cooling system is modeled as a straight tube 0.3 cm in diameter, 20 cm long, transporting liquid ammonia (under pressure, if need be, to keep it liquid) at 2 m/s. The component temperature must not exceed 50° C. The heat is exhausted to a radiator at 20° C. The physical properties of ammonia are tabulated on page 168 of Karam. (*a*) Calculate the heat transport capacity of this system. (*b*) Calculate the power necessary to pump ammonia under these conditions.